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INFLUENCE OF SURFACE COATINGS ON EXO-ELECTRON EMISSION DURING FATIGUE

UNPUBLISHED PRELIMINARY DATA

QUARTERLY PROGRESS REPORT NO. 6
1 December 1962 - 1 March 1963

Task Order Contract No. NASr-63(02)

M.R.I. Project No. 2553-P

[redacted]

For

Office of Grants and Research Contracts
Code SC
National Aeronautics and Space Administration
Washington 25, D. C.

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by

J. C. Grosskreutz
David Benson

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PREFACE

This report covers the research performed during the period 1 December 1962 - 1 March 1963 under Contract No. NASr-63(02), M.R.I. Project No. 2553-P. The research was directed by Dr. J. C. Grosskreutz and is under the supervision of Dr. Sheldon L. Levy, Director, Mathematics and Physics Division. Mr. David Benson carried out much of the experimental work reported here.

Approved for:

MIDWEST RESEARCH INSTITUTE

Sheldon L. Levy, Director
Mathematics and Physics Division

22 March 1963

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I. INTRODUCTION

During the past quarter we have continued our direct measurements of exo-electron emission from fatiguing aluminum in an effort to obtain more reproducible data. The ultra-high vacuum device for determining the effects of surface films and environment on exo-electron emission has been constructed and leak-tested. Tunnel-emitting diodes have also been constructed for use as calibration sources in the exo-electron experiments. Finally, consideration has been given to ways of measuring the oxide layer thickness on the exo-emitting samples.

II. EXPERIMENTAL WORK

A. Direct Detection of Exo-Electrons during Fatigue

Further effort has been expended to measure exo-electron emission from a cyclicly stressed aluminum sample. Noise has been minimized in the electronic circuitry, and a pulse height analyzer has been incorporated to select the electron pulses from the noise spectrum (Fig. 1). Because of the extremely low energy of the exo-electron, some attention must be given to the problem of signal-to-noise ratio. The dark current collected at the last dynode in the electron multiplier is given by:

$$I_d = \sum_{i=1}^{k} na^{(i-1)}$$

where n is the number of dark current electrons per stage per second; a is the gain per stage; and k is the number of stages. To a good approximation, if $a \approx 2$,

$$I_d \approx na^{(k-1)}$$

The dark current is of the order of 10^{-9} amperes, thus $n \approx 10^4$ electrons per second. This number is equal to, or perhaps even greater than the expected exo-emission rate under study. Therefore, our signal will be buried in the noise unless we make provision to: (1) accelerate the exo-electron striking the first dynode sufficiently to insure the maximum multiplication, and (2) discriminate between the slightly larger output pulses due to exo-electrons and the noise pulses. The circuitry shown in Fig. 1 accomplishes both these aims.

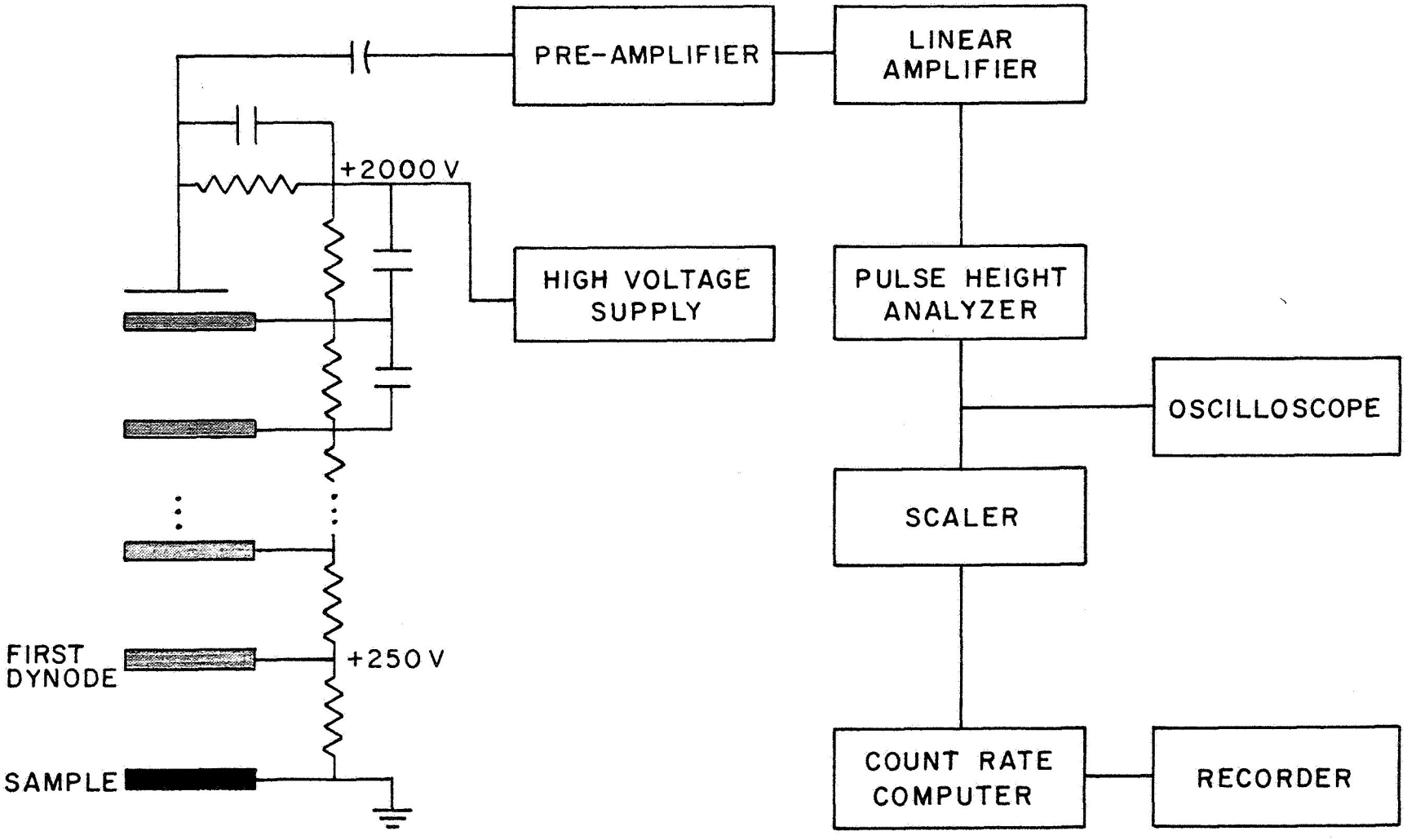

Fig. 1 - Block Diagram of Electron Detecting Circuit

Another measurement of the emission from 2S aluminum in a vacuum of 5×10^{-5} Torr and total darkness has just been accomplished (Fig. 2). The sample developed extensive slip and cracked in two places. Due to a fault in the monitoring apparatus, sample failure was not detected; but we believe it occurred at the 31-minute mark. As can be seen, the signal-to-noise ratio is high. The stochastic nature of the pulse counting rate is to be expected since the cracks propagate in more or less random fashion. The early rise in counting rate is probably due to the buildup of slip. Some time is required for the sample to work harden; then the cracks begin to propagate. The high counting rate continues until sample failure.

A counting rate computer and continuous recorder are to be added to the system. We will also attempt to enhance the emission by admitting oxygen into the sample chamber. For this purpose, the silver oxygen-diffuser will be used to obtain a residual atmosphere of $\sim 5 \times 10^{-5}$ Torr of oxygen.

B. Effect of Surface Films on Exo-Electron Emission

The apparatus for the ultra-high vacuum and controlled atmosphere experiments has been obtained and partially assembled. The vacuum system to which the sample chamber will be attached (Fig. 3) is completed and regularly attains a vacuum in the 10^{-10} Torr range. The final design of the sample chamber (Fig. 4), permits us to reproducibly strain aluminum sheet samples in vacuum while recording the electron emission rate. We will also be able to illuminate the surface of the sample to test for an enhanced photoelectric effect. Electrical leads are provided for a calibration source of electrons.

The calibration source will be a small three-layer evaporated film device similar to those reported by Kanter and Fiebelman[1] (Fig. 5). A tunneling current is passed through the oxide coating of an aluminum film to a thin gold surface electrode. When sufficient voltage is developed across the diode, some of the electrons penetrate the gold layer and escape into the vacuum. Such a device is advantageous because it is simple, small, durable and the electrons are emitted with low energy. A further advantage is that no light accompanies this electron emission, so that electron multiplier calibration can be carried out in total darkness.

We have already fabricated some electron emitting diodes similar to those reported by Cohen,[2] but they were not successful. The design of Kanter and Fiebelman appears to be more simple and rugged, and we are now constructing several of these diodes.

1/ Kanter, H., and Fiebelman, W. A., J. Applied Phys., Vol. 44, pp. 3580-8 (1962).

2/ Cohen, J. Applied Phys. Letters, Vol. 1, pp. 61-3 (1962).

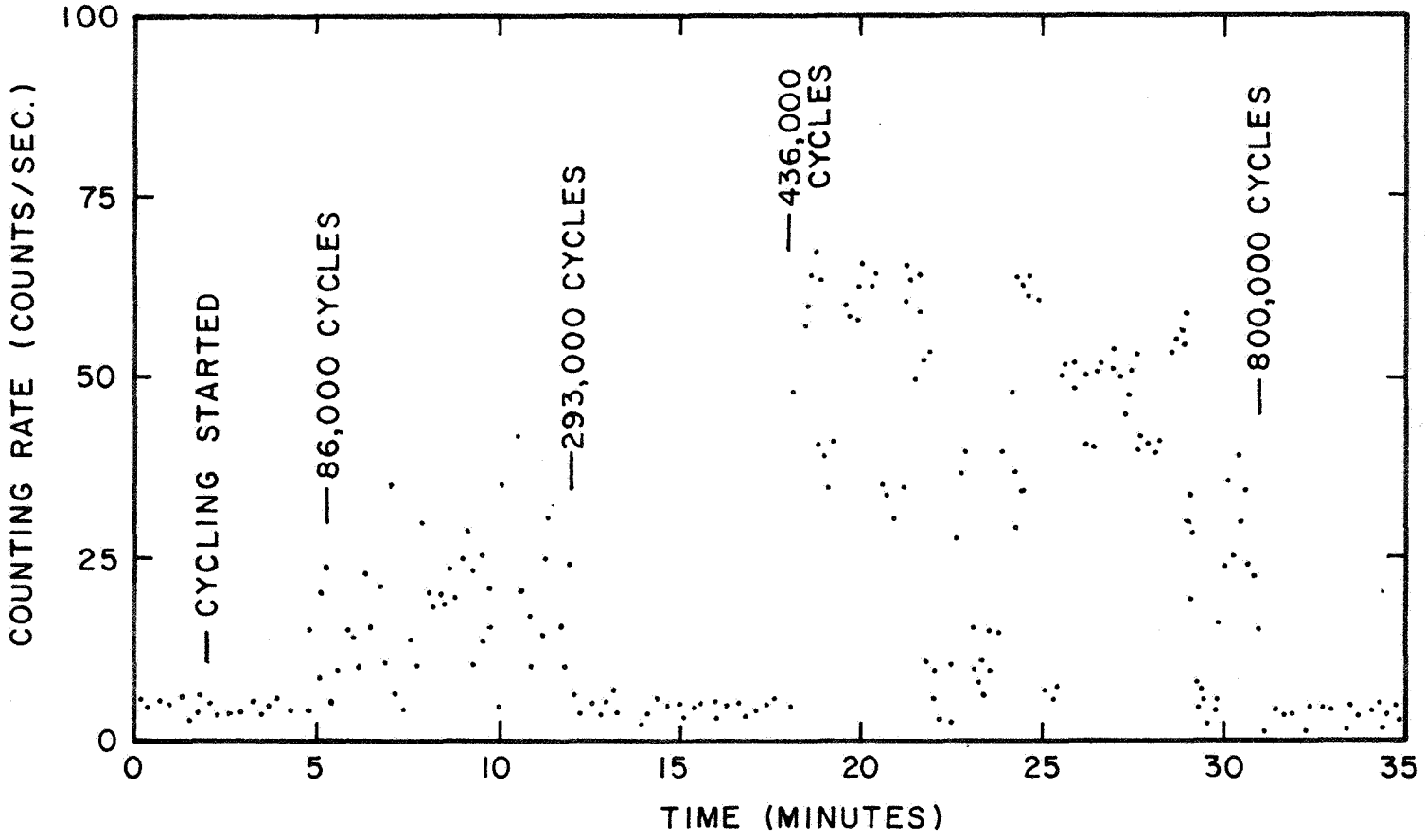

Fig. 2 - Exo-Electron Counting Rate for Cyclicly Stressed 2S Aluminum in 5 x 10^{-5} Torr Vacuum

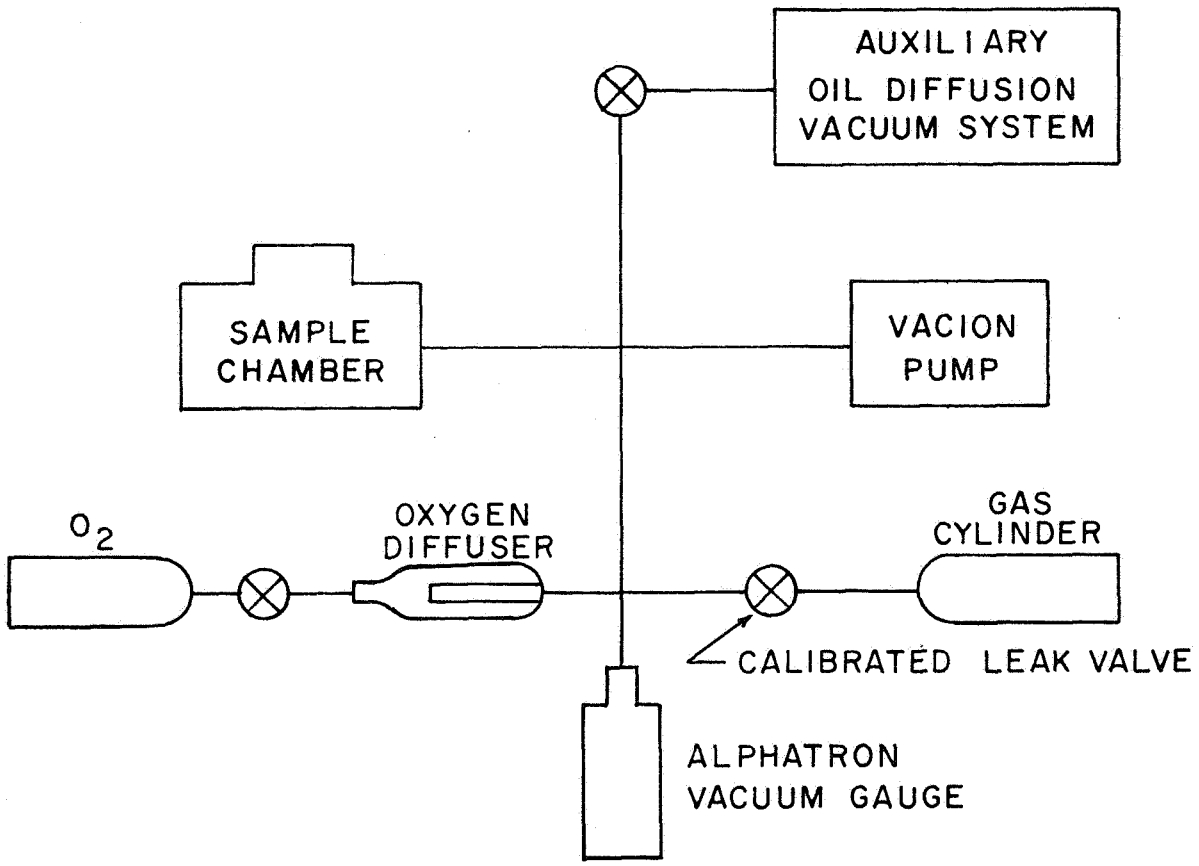

Fig. 3 - Block Diagram of Ultra-High Vacuum System

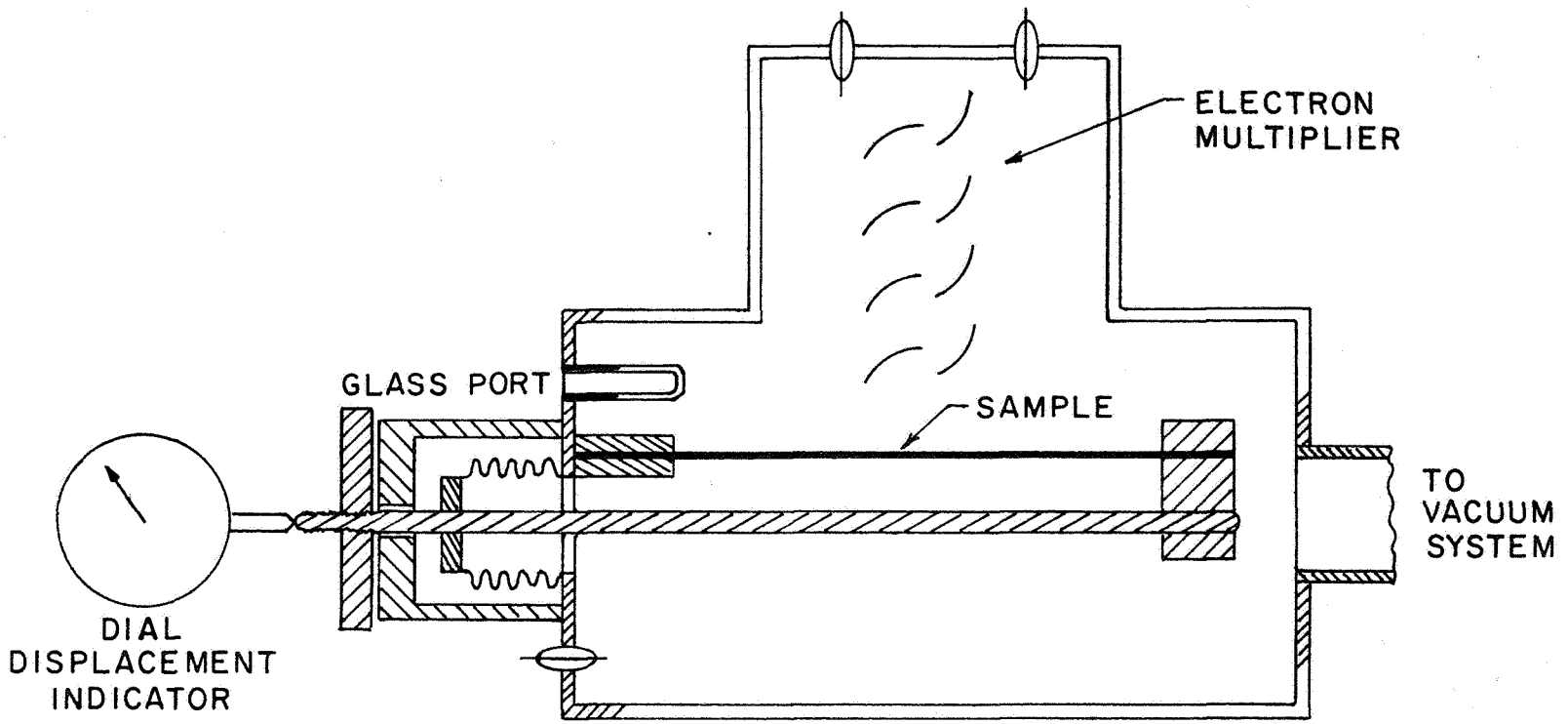

Fig. 4 - Simplified Cross Section of Sample Chamber

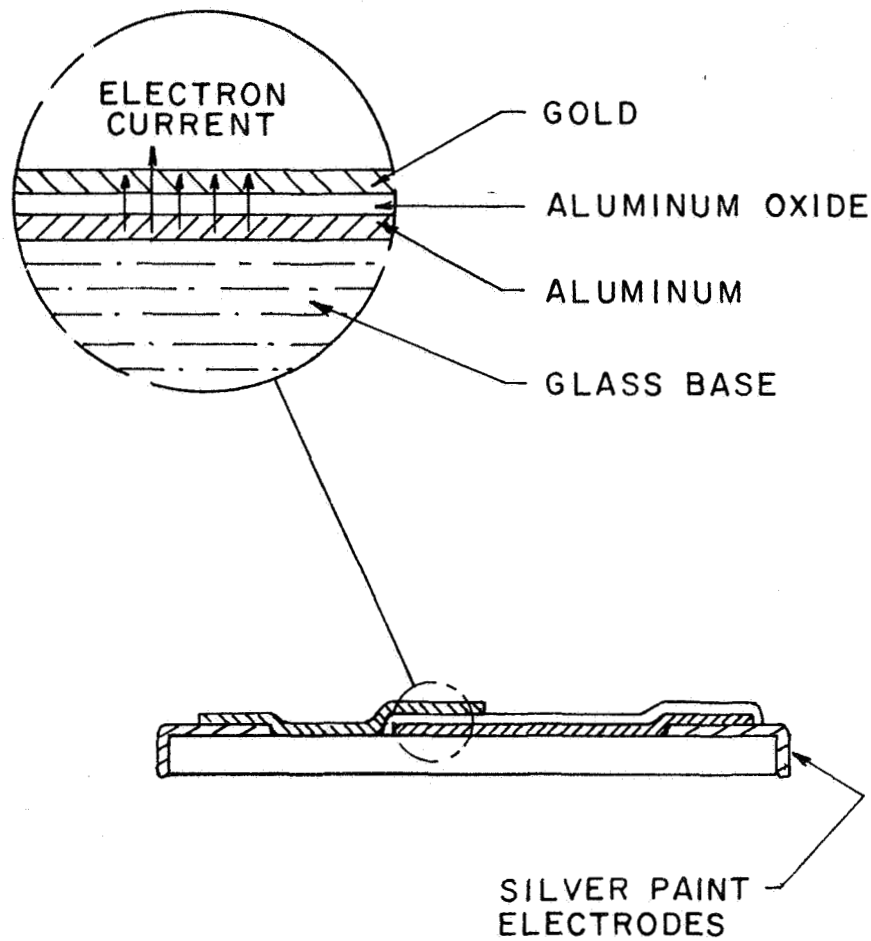

Fig. 5 - Simplified Cross Section of Electron Emitting Diode

III. DISCUSSION AND PLANS FOR FUTURE WORK

Although we have established beyond doubt that exo-electrons are emitted in measurable numbers during fatigue of aluminum, we still do not have a reliable number for the emitted intensity. This intensity can be expressed as a per cycle rate, in which case a strong dependence on the applied stress level will occur; or one can simply quote an integrated intensity per unit area for complete fatigue fracture. To begin with, the latter definition appears to be more useful. However, until we have a better means of calibration for our electron multiplier, any number which we might compute from the data of Fig. 2, would be subject to rather large errors. To obtain a good figure for the emission intensity will continue to be one of our prime objectives.

The experiment to study the effect of oxide layers and environmental gases on exo-electron emission[3/] will provide us with much needed data on the mechanism of emission. We have incorporated into the apparatus means for testing for enhanced photoemission after strain stimulated emission has decayed to zero. The result of such a test will have significance, both delineating the source of exo-electrons and possible application of the emission as a plastic-strain indicator.

We further anticipate the need for examining exo-electron emission from aluminum surfaces which have been stripped of their oxide layer. To this end, we are initiating experiments to test the effectiveness of atomic hydrogen in removing this oxide. The atomic species will be produced by admitting molecular hydrogen into the vicinity of a hot tungsten filament placed near the sample to be stripped. Measurement of the residual layer will be carried out by either (1) measurement of the photoelectric wash function, or (2) measurement of the recombination rate of atomic hydrogen on the stripped surface.

3/ Quarterly Progress Report No. 5, dated 13 December 1962.